TILLAGA – *PROPOSAL*

Breiðdalseldstöð-Geopark

Breiðdalshreppur & Djúpavogshreppur
Austurland

Breiðdalur Central Volcano – Geopark

Breiðdalsvík/Breiðdalur & Djúpivogur

East Iceland

Mynd 1. Fjallakeðjan á milli Berufjarðar og Breiðdals séð til austurs. Ljósa bergið á tindum og skriður þeirra er líparít. Tindarnir voru aðrennslisgígar Breiðdalseldstöðvar sem liggja á fyrrverandi slóða eldfjallsins. Frá vestri til austurs: Flögutindur, Smátindar, Röndólfur, Slöttur og Stöng.
Mynd eftir Skarphéðinn G. Þórisson.

Figure 1. The mountain range between Berufjörður and Breiðdalur viewed to the east. The peaks with light coloured talus slopes are rhyolite vents and plugs, located on the eastern flank of the ancient Breiðdalur volcano. From west to east they are: Flögutindur, Smátindar, Röndólfur, Slöttur and Stöng. The assumed origin of the Skessa ignimbrite is close to the mountains in the foreground fig 36 stop 10. Photo by Skarphéðinn G. Þórisson.

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1. Inngangur - samantekt

Breiðdalseldstöð var virkt eldfjall fyrir rúmlega 9 milljón árum, hún liggur á milli Berufjarðar og Breiðdals í landi Djúpavogshrepps og Breiðdalshrepps. Jöklarnir á ísöld hafa rofið landslagið þannig að hægt er að sjá inn í kulnaða eldstöðina. Ísöld lauk fyrir rúmlega 12.000 árum. Fleiri en 10 slíkar eldstöðvar finnast á Austurlandi.

Sérstaða Breiðdalseldstöðvar er hins vegar að hægt er að keyra í kringum hana, ganga upp að henni og yfir hana. Nánast öll stig í lífi eldfjallsins eru sjáanleg einhvers staðar á því svæði sem hér er lýst (mynd 2). Það er einstök upplifun að ganga og skoða sig um "í innviðum eldfjalls“ eins og hægt er í tilfelli þessarar eldstöðvar.

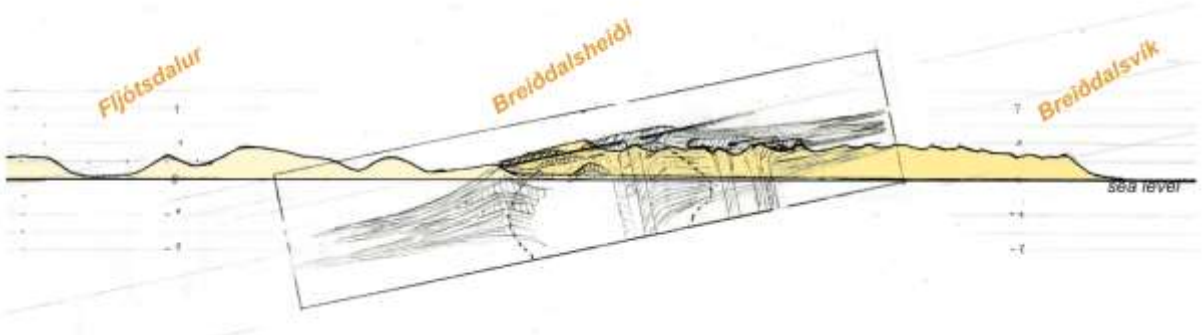
Kjarninn og aðalgígur eldstöðvarinnar var í kringum fjallið Matarhnjúk (912 m), en tindarnir á milli Breiðdals og Berufjarðar Stöng, Slöttur, Smátindar, Flögutindur og Berufjarðartindur voru einnig gígar eldfjallsins (Walker 1963) mynd 1. Þeir eru gerðir úr rhýoliti og eru harðari heldur en umhverfið, sem leiðir til þess að þeir standast veðrun lengur.

Einnig liggur hinn heimsfrægi staður Teigarhorn á svæðinu, en þar hafa fundist flestir og stærstu zeolítar í heiminum (sjá bls. 7.)

Langtímahugmynd er að gera svæðið í kringum óvirka eldfjallið í Breiðdal (Breiðdalseldstöð) að svokölluðu „European Geopark“, sem vísar til sérstakra jarðfræðifyrirbæra: http://www.europeangeoparks.org/ . Um merki er að ræða, svipað og gæðamerki á vörum.
Verkefnið er ekki komið í formlegan feril en þetta skjal er upphaf verksins, til að kanna áhuga viðkomandi aðila á svæðinu, sveitarfélaganna Breiðdalshrepps og Djúpavogshrepps og ferðaþjónustuaðila á svæðinu. Breiðdalssetur er stofnun sem leggur megináherslu á jarðfræði svæðisins og er því í forsvari verkefnisins.
Til að geta sótt um merkið þarf mikla undirbúningsvinnu. Eftirfarandi gögn þurfa að vera til:

*Bæklingur sem lýsir jarðfræði svæðisins.
*Merktar gönguleiðir og kort
*Jarðfræðileg upplýsingamiðstöð (Breiðdalssetur og Teigarhorn)
*þjónusta á borð við salerni, veitingastaði o.s.frv

Ástæða þess að Breiðdalseldstöð kemur til greina í þessu verkefni er að Ísland er frægt fyrir eldvirkni þó að einungis lítill hluti eyjunnar tilheyri virka gosbeltinu. Hægt er að markaðssetja Austurland með því að vekja athygli á þeim eldstöðvum sem hér er að sjá. Áhugavert fyrir fólk er að sjá annars vegar virk eldfjöll á gosbelti Íslands, eins og t.d. Öskju eða Kötlu (Kötlusvæðið er þegar orðið geopark) og hins vegar óvirk eldfjöll og innviði þeirra, sem ekki er hægt að sjá á virkum eldfjöllum.
Kynning á þessu er mikilvæg til að draga athygli fjölbreyttra hópa ferðamanna austur á land. Merkið European Geopark myndi styrkja ferðaþjónustu á svæðinu til muna. Sem stendur er Breiðdalssetur að leita eftir fjármagni til að gefa út bækling með stuttum lýsingum af þeim jarðfræðifyrirbærum sem sjá má í kringum Breiðdalseldstöðina.



Mynd 2. Handteiknuð mynd sem sýnir staðsetningu Breiðdalseldstöðvar í núverandi landslagi, séð að sunnan. Teikningin í kassanum er eftir Walker 1963, en tenging landslags við frumteikningu eftir M. Gasser starfsmann Breiðdalsseturs 2016.

Figure 2. Coloured hand sketch showing the spatial position of Walker's profile of the fossil Breiðdalur Central Volcano (fig.31) in a topographic profile of Breiðdalur valley. The mountain range along the valley is shaded slightly darker yellow. By M. Gasser after Walker, 1963. Vertical exaggeration 2x.

Mynd 3. Tillaga um útlínur fyrir Breiðdalseldstöð geopark. Útlínur fylgja fjallgarðinum á milli Stöðvarfjarðar og Breiðdals, Fáskrúðsfjarðar og Breiðdals, síðan á Breiðdalsheiði fylgja mörkin Axarvegi og síðan fjallakeðjunni við Berufjörð út á Djúpavog.

Figure 3. Suggestion for outline of the proposed „Breiðdalur Volcano Geopark", see figure 4 for localities of special character.

2. Áhugaverðir staðir á tilgreinda svæðinu, sjá nánar á bls. 5-26 (á ensku)

1. Djúpivogur – Gangasveimur Álftafjarðareldstöðvar

2. Teigarhorn & Búlandstindur – Verndaður fundarstaður steinda auk steinasafns og jökla sem mynda fjallapíramíða.

3. Vegamót þjóðvega 1 & 939 (Öxi) - Breiðdalseldstöð: Suðurhlið eldfjallsins, samsett hraunlag (basalt og líparít), aðrennslisgígar Breiðdalseldstöðvar

4. Blábjörg flikruberg – Myndbreyttur túff, sambrætt gjóskubergslag

5. Karlsstaðir - Gangasveimur Álftafjarðareldstöðvar framhald (1), veitingastaður

6. Streitishvarf – Blandaður gangur, suðurendi af ≥15km löngum gangi, blandberg

7. Breiðdalsvík - Sylla, Breiðdalssetur- jarðfræðisetur (Gamla Kaupfélagið), lítið steinasafn

8. Vegamót 1 & 966 – Breiðdalseldstöð: Botn, yfirsýn yfir uppbyggingu eldstöðvar

9. Jórvík - Breiðdalseldstöð: yfirsýn um uppbyggingu fjallshlíðar eldstöðvar og kjarninn.

10. Skessutúff, opna við Skriðuárbrú á veginum 966 – Breiðdalseldstöð: Skessutúff sambrætt gjóskubergslag, leiðarlag Breiðdalseldstöðvar, stærsta flikrubergslag á Íslandi. Líklega eitt af fyrstu gosum eldstöðvar.

11. Hesthálsá, brekka upp á Breiðdalsheiði - Breiðdalseldstöð: Kjarninn og toppur. Öskjuvatnssetlög, súrt gosberg á seinni hluta virkni eldjallsins. Flæðibasalt sem urðaði eldstöðina.

2. Sites of interest in proposes area, detailed on p. 5-26

1. Djúpivogur - Dyke swarm of Álftafjörður central volcano

2. Teigarhorn & Búlandstindur – Protected mineral site, glacial pyramid carving

3. Cross road nr. 1 & 939 (Öxi) - Breiðdalur central volcano - Southern flank of volcano edifice, composite lava, silicic vents and plugs

4. Blábjörg ignimbrite - Low-grade metamorphic welded tuff horizon

5. Karlsstaðir farm- Álftafjörður dyke swarm cont., Restaurant

6. Streitishvarf - Composite dyke, southern end of a ≥15km long mafic/felsic composite dyke

7. Breiðdalsvík - Dolerite sill, Walker Centre (Breiðdalssetur/Gamla Kaupfélagið), rock sample collection.

8. Cross road – nr. 1 & 966 - Breiðdalur central volcano, bottom view, Breiðdalur Valley, bottom of fossil volcano edifice, overview internal structure of volcano flank

9. Jórvík - Breiðdalur central volcano: Overview of volcano flank to core transition

10. Outcrop near bridge over river Skriðuá on road 966 - Breiðdalur central volcano: skessa welded tuff, marker horizon, probably one of the first eruptions of the Breiðdalur volcanic centre

11. Hesthálsá, slope Breiðdalsheiði pass - Breiðdalur central volcano: Core and top view, crater lake sediments, acid late stage volcanics, flood basalts burying volcano

3. Field guide to sites of interest in proposed Breiðdalur volcano Geopark

Fig.3 Locations of excursion stops described in this chapter. Image: Landmælingar Íslands

Stop 1

Djúpivogur

Dyke swarm of Álftafjörður central volcano.

Location: 64,6555°N/14,276°W. Parking space near a radio mast behind Djúpivogur school building.

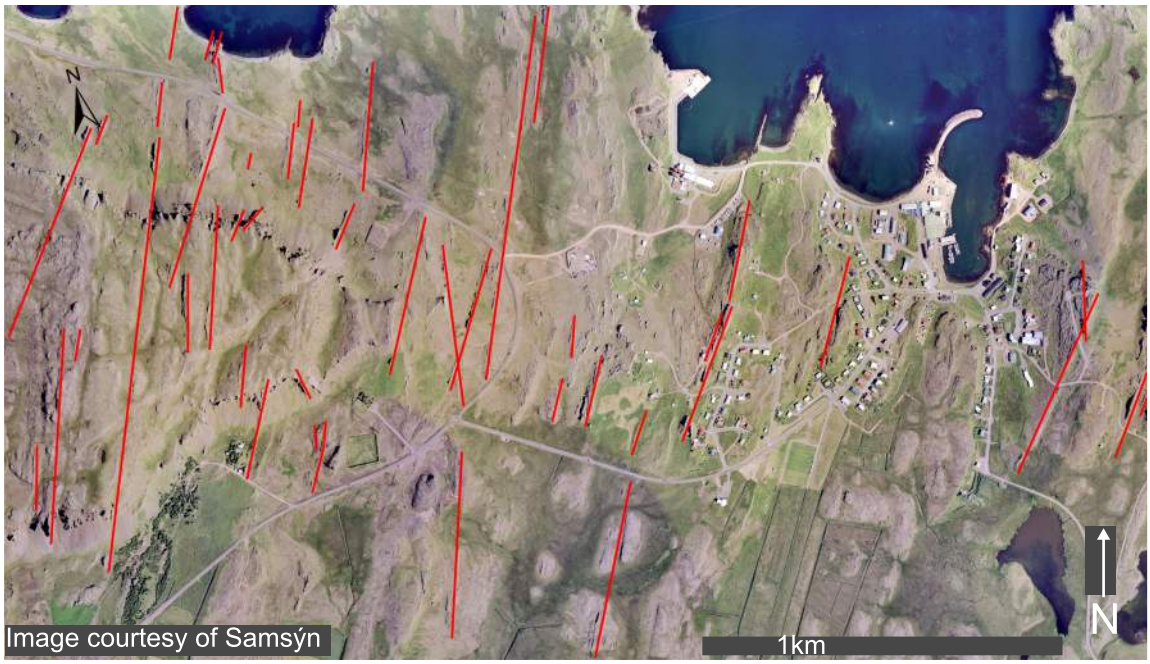


Fig.4. Aerial view of Djúpivogur village, situated within the dyke swarm related to Álftafjörður central vol-cano. The stop location lies 300m N of upper left corner of the image. Some dykes are traced with red lines.

The village of Djúpivogur as well as the farm Teigarhorn (Stop 2) are built within the Álftafjörður dyke swarm, the position and alignment of the houses being influenced by the dykes.

A dyke in the geological sense is an intrusion of magma into a crack or fissure. The magma most often gets stuck and solidifies, but sometimes a dyke intrusion reaches the surface and causes a fissure eruption, in which case the dyke is called a feeder dyke.

Most of the magma produced by icelandic volcanic systems rises along cracks in the rift zone and erupts from fissures fed by dykes, often far away from the volcanic centre. Over time, repeated eruptions produce more fissures, resulting in a swarm of fissures and dykes along the rift in both directions from the volcanic centres. See fig.5 and stop 5. The dyke swarm of the Álftafjörður volcanic system is not visible in Álftafjörður itself, but is conspicous from about Hamarsfjörður to Breiðdalur. In Breiðdalur, it is getting unclear whether the dykes adhere to Álftafjörður or to Barðsnes volcanic centre further north.

The connection between central volcano (i.e. volcanic centre) and associated dyke swarm is still a matter of research. Why for example are the dyke swarms often not continuous through their volcanic centres? It is also difficult to connect a dyke swarm clearly to one centre, since the swarms interdigit a lot. The huge fissure eruptions of Laki in the year 1783 and Eldgjá around 935 A.D. are recent examples for this. They are only 5km apart and parallel one another over a distance of about 20km, their corresponding centres being 120km apart (Grímsvötn centre for Laki and Katla centre for Eldgjá). By the way, they were the biggest lava eruptions in historic record, with volumes of about 15km^3 (Laki) and 18km^3 (Eldgjá).

Fig.5. Part of the Álftafjörður dyke swarm at Karlsstaðir stop 5, vis-à-vis of Djúpivogur, on the northern side of Berufjörður fjord. Conveniently, a restaurant was opened in 2016 in the (renovated) house in the foreground.

Stop 2

Teigarhorn and mount Búlandstindur (1069 m)

Protected mineral site, glacial pyramid carving

Locations: 64,676°N/14,345°W for Teigarhorn visitor center and **64,6724°N/14,338°W**, parking space on the seaside of road nr.1, 500m SE of Teigarhorn. Blábjörg ignimbrite view towards N (stop 4) and beach outcrop of Blábjörg ignimbrite 200m to the W of parking space.

Fig.6. The land and farm Teigarhorn and Búlandstindur mountain (1069 m). It is the highest mountain wall rising from sealevel in Iceland. Picture from Teigarhorn homepage (teigarhorn.is).

From the stop site towards the W, the pyramid-shaped Búlandstindur (1069m) cannot be overseen (fig. 6). It is the highest peak in Iceland rising directly from the sea and it is entirely built up of flood basalts. Its magnificent silhouette has been carved out by two valley glaciers and two corrie glaciers.

Teigarhorn is a farm situated about 5 km east of the village of Djúpivogur (fig. 7). In 1975 it was, along with its lands, declared a geological monument. The grounds of Teigarhorn are rich in zeolites and are the site where the biggest scolecites worldwide have been found. The Icelandic government purchased the site in 2013 and simultaneously the Ministry of Environment declared it a place of cultural heritage.

The special thing at this locality is, the rare possibility to observe minerals in cavity fillings, that are still in the rock, where the growed millions of years ago. World famous is Teigarhorn for its Scolecite crystals (zeolite type). The largest crystal needles in the world were reported here (fig 8).

Fig.7. Teigarhorn farm, photo taken in 2013. The old farmhouse is in the back, it is a cultural heritage. The house in the front contains the Teigarhorn stone museum.

A stone museum shows minerals found on Teigarhorn land. Both the mineral collection at Teigarhorn and a part of the farmland is open to the public. Visitors are welcome to hike along marked paths of this beautiful coastal farmstead, but keep in mind that the zeolites are protected and cannot be collected from the rock or picked up from the land.
Teigarhorn as well as the village of Djúpivogur (stop 1) are situated within the Álftafjörður dyke swarm that belongs to Álftafjörður volcanic system. The dyke swarm is the reason why crystals are specially large in this area. The dykes supported heat which is nessacery for mineral formation.
The ignimbrite described at stop 4 is visible at the shore of Teigarhorn as well.

Fig.8. Several zeolite types in cavity filling at Teigarhorn. The fibrous type is scolecite. The largest crystals of this type have been found in Teigarhorn (with needles about 20 cm long). The image is about 20 cm wide. By R. Askew.

308.8 (above) and 9. Giant amygdales, lined with quartz and chalcedony, in tholeiite lava, shore at Teigarhorn, Berufjördur. The one above measures 4 ft wide by 3½ ft. deep by 10 ins.high. Scale given by six-inch rule.

Fig.9. The same chalcedony cavity filling in basalt at the shore of Teigarhorn. The upper photographs were taken by G.P.L. Walker in 1957 & 1962. Lower left taken in 2016 by R. Gesemann; Lower right with the main author of this book M. Gasser (left) & coauthor L.G. Gústafsson (right) taken by A. Blischke in 2014.
Notice that roughly half of the cavity filling has been washed away by the sea in half a century.
During the growth of the finger like structures, they were hanging vertically down, today they are tilted due to regional tectonics of Iceland (chapter 1). Walker found out though that the tilt is slightly less than the one of the lava pile, because they formed some million years later.

Stop 3

Breiðdalur central volcano, southern flank

Flank of volcano edifice, composite lava, silicic vents and plugs.

Location: 64,797°N/14,524°W. Bottom of Berufjörður fjord, at the junction of road nr. 1 and road nr. 939 (Öxi pass road).

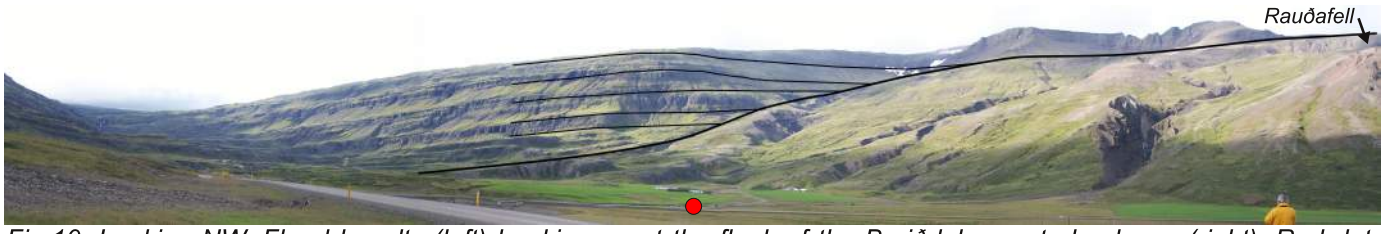


Fig.10. Looking NW. Flood basalts (left) banking up at the flank of the Breiðdalur central volcano (right). Red dot: location of stop 3.

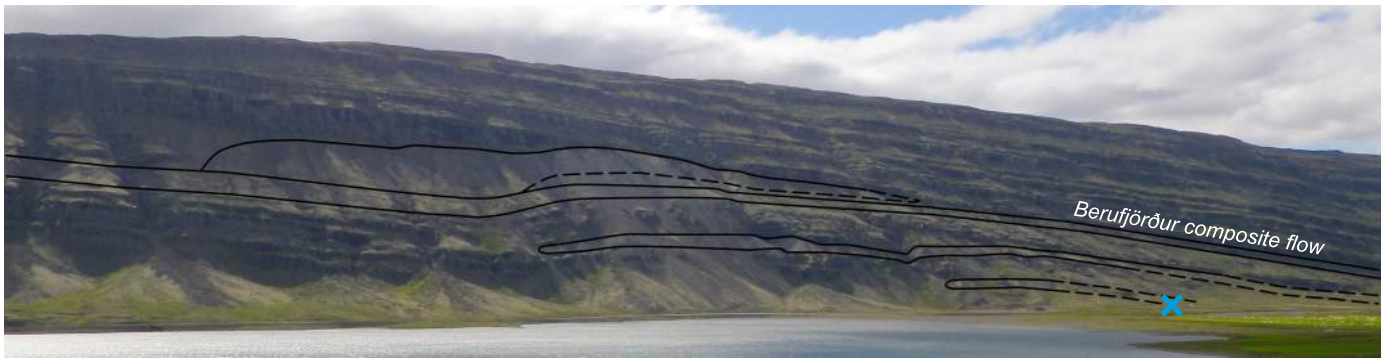


Fig.11. The north flank of Fossárfell. Blue cross is where fig.10 was photographed. Rhyolite flows are indicated.

Among the ancient volcanoes of eastern Iceland, the Breiðdalur central volcano is especially well exposed and accessible from different angles. Here in Berufjörður, the erosional surface of the northern side of the valley loosely corresponds to the original flank of the volcano at some point during its life. This permits us to see the later flood basalt layers bank up against the volcano edifice (fig.10). The hill Rauðafell (fig. 10) marks an eruptive vent with its feeder dyke (see fig.12). This eruption has produced a fine example of a composite lava flow. It is exposed on the S side of the valley (fig.11), best accessible in gullies, e.g. at 64,787°N/14,523°W. The lava flow consists of a 2-3m thick porphyric basalt base overlain by 30-40m of simultaneously erupted composite rhyolite/basalt. Chilled basalt xenoliths of cm to dm size are mingled, not mixed, with the rhyolite. (Charreteur & Tegner, 2013). This mingling is thought to take place in the magma chamber, producing a net-veined complex similar to the one at Eystrahorn SE-Iceland. A possible eruption mechanism and feeder dyke for such a lava are explained at Streitishvarf (stop 6).

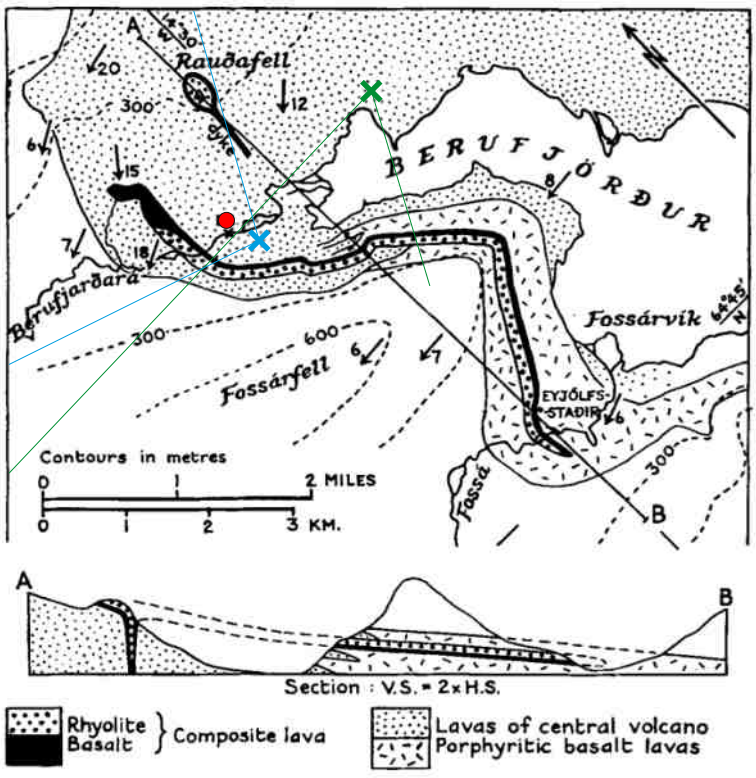


Fig.12. Map and section of the Berufjörður composite flow and Rauðafell. Red dot: location of stop 3. Crosses: Position of Photographer and field of view (blue: fig.9, green: fig.10). Modified after Gibson & Walker 1964.

This was a view onto and inside the flank of the Breiðdalur central volcano. We will visit its base, core and top in Breiðdalur valley, behind the magnificent mountain chain on the N side of Berufjörður. The rugged peaks are remnants of late acid eruptions of this volcano.

Stop 4

Blábjörg ignimbrite

Low-grade metamorphic welded tuff horizon

Location: 64,707°N/14,314°W. Parking on the S side of the road, The outcrop is a rock cliff right below at the beach, 200m from the road. The site is protected, no hammering or removal of rocks is allowed.

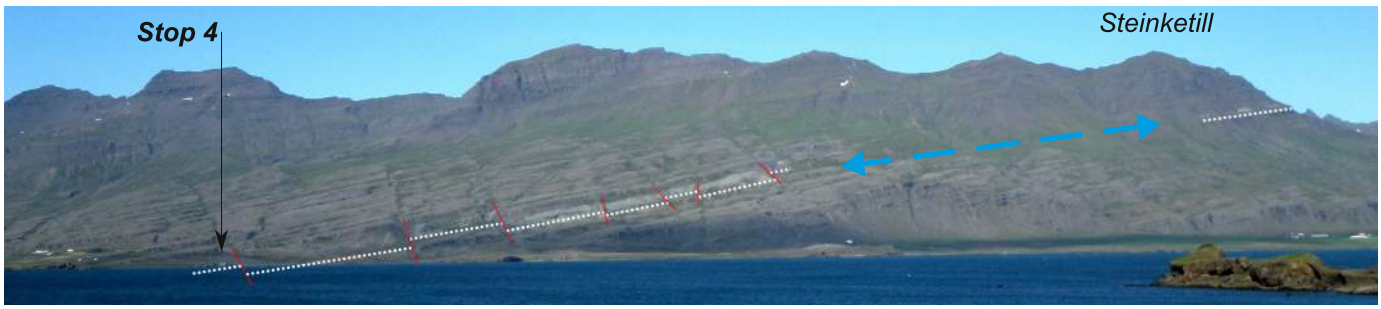


Fig.13. View from Teigarhorn (stop 2). The Blábjörg ignimbrite is underlined by the dotted line. It stretches as a blue-greenish layer from the beach up to ca. 500m a.s.l., it is slightly faulted and hidden under scree behind the blue arrow.

The Blábjörg ignimbrite forms a distinctive blue-greenish breccia layer near the mouth of Berufjörður. It is well visible from the road, also from the opposite side of the fiord (fig.13). From the stop site, it can be traced to the E for more than 5 km up-slope and around the nose of Steinketill mountain. To the S, the layer enters the sea and reappears at Teigarhorn (64,6737°N/14,3412°W), 200m from stop 8.

The ignimbrite is characterized by slightly flattened bright-green clasts giving the rock its breccious appearance. Their porosity identifies them as pumice fragments.

Ignimbrites are the deposits of extremely violent, pyroclastic explosive eruptions. Dense, hot (>800°C) clouds of volcanic ash, pumice, rock and gas incinerate the landscape, flowing at hundreds of km/h, leaving a steaming blanket of material, in this case so hot that the glassy particles fused together and the pumice got compressed under the weight of the flow. The deposit overlies an aa-lava flow. During the first surge of the eruption, ash was injected into the rubbly lava surface while the soil was rapidly eroded.

Fig.14. Beach outcrop at stop 4. The cliff is called Blábjörg (blue cliff). The red horizon marks the bottom of the ignimbrite, it represents the ground surface soil at the time of eruption. It got eroded and reworked by the pyroclastic flow and integrated into the ignimbrite. Cliff height ~6m. The background is dominated by Búlandstindur pyramid (1069m).

The ignimbrite's internal structure shows changes in the amount of lithics (=clasts of surrounding rock) and pumice, reflecting changes in dynamics during eruption. More lithic fragments indicate a widening or merging of the vent. Along the beach at the other end of the cliff, a top layer of ash is exposed, presumably a fallout deposit after the dense pyroclastic flow had settled.

The flow direction or the position of the vent from which it was erupted were not found so far.

The Tittlingshagi ignimbrite lies well below the Skessa Tuff (stop 10) which in turn is overlain by the Grænavatn Porphyritic Group flood basalts at the base of Breiðdalur central volcano. In literature, the Blábjörg ignimbrite is sometimes mistaken as the Skessa tuff.

Stop 5

Álftafjörður dyke swarm: Karlsstaðir farm

Dyke swarm, same as in stop 1, Restaurant and guesthouse

Location: 64,696°N/14,229°W. Sign on main road, Havari

The farm area of Karlsstaðir lies within the Álftafjörður dyke swarm, as well as the village of Djúpivogur (stop 1 the farm Teigarhorn (stop 2).

A dyke in the geological sense is an intrusion of magma into a crack or fissure. The magma most often gets stuck and solidifies, but sometimes a dyke intrusion reaches the surface and causes a fissure eruption, in which case the dyke is called a feeder dyke.

Most of the magma produced by icelandic volcanic systems rises along cracks in the rift zone and erupts from fissures fed by dykes, often far away from the volcanic centre. Over time, repeated eruptions produce more fissures, resulting in a swarm of fissures and dykes along the rift in both directions from the volcanic centres. The dyke swarm of the Álftafjörður volcanic system is not visible in Álftafjörður itself, but is conspicous from about Hamarsfjörður to Breiðdalur. In Breiðdalur, it is getting unclear whether the dykes adhere to Álftafjörður or to Barðsnes volcanic centre further north.

Fig.15. The Álftafjörður dyke swarm at Karlsstaðir farm north of Djúpivogur village (fig. 4 and 5). The dykes are well visible in this areial photo map as elongated rock units, lying SSW to NNE. At the farm is a guesthouse and a restaurant as well

Fig.16. Álftafjörður dyke swarm going into the sea (fjord Berufjörður), south of Karlsstaðir farm. It appears again on land in Djúpivogur village (stop 1) and Teigarhorn (stop 2). It occurs again more south in Hamarsfjörður. It is originated in the the extinct volcano of Álftafjörður. Picture by Skarphéðinn G. Þórisson.

Stop 6

Composite dyke at Streitishvarf

Southern end of a ≥15km long mafic/felsic composite dyke

Location: 64,7305°N/13,989°W. Parking next to an aerial station, 150m from the lighthouse at the tip of the peninsula between the fjords of Berufjörður and Breiðdalsvík, seawards of Road nr.1.

Immediately after turning off from road nr.1, we cross the composite dyke which is hidden under a thin but swampy soil cover. The roadsign "Streitishvarf" is put exactly on top of it. The dyke crops out at the beaches in the N and in the S, the parking lies right in between.

The sites are at a 10-minute walking distance each, a path is marked by red-topped green poles. The southern outcrop (fig. 20) is more nicely accessible, the northern one (fig. 18) offers a great view of the dyke as it cuts through the whole mountain range further in the north. It is recommended to visit both sites because of the scenic beauty of the place. In summer, there is a chance to meet some rather self-confident icelandic goats on (in) the way. Be nice to them, they are in danger of extinction.

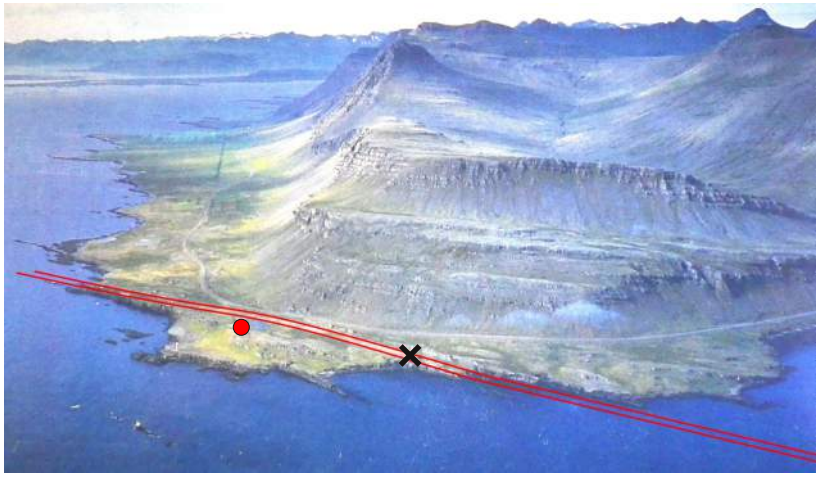


Fig.17. Location of stop 11 on Streitishvarf peninsula (red dot). Black cross: Viewpoint of Photographer in fig.72. The two red lines mark the margins of the composite dyke. It is unknown how far the dyke continues south (left) into the sea.

The 10.2 million year old Streitishvarf composite dyke consists of a 15-m-thick central felsic area of bright quartz porphyry rock with dark mingled-in mafic enclaves , enclosed on each side by 5-m-thick mafic dolerite margins. Between the centre and the margins is a narrow zone of hybrid rock, formed by mechanical mixing of the felsic core and the mafic margins (fig. 21). The margins look like independent parallel dykes, but they were intruded simultaneously with the composite rock in between. The dyke can

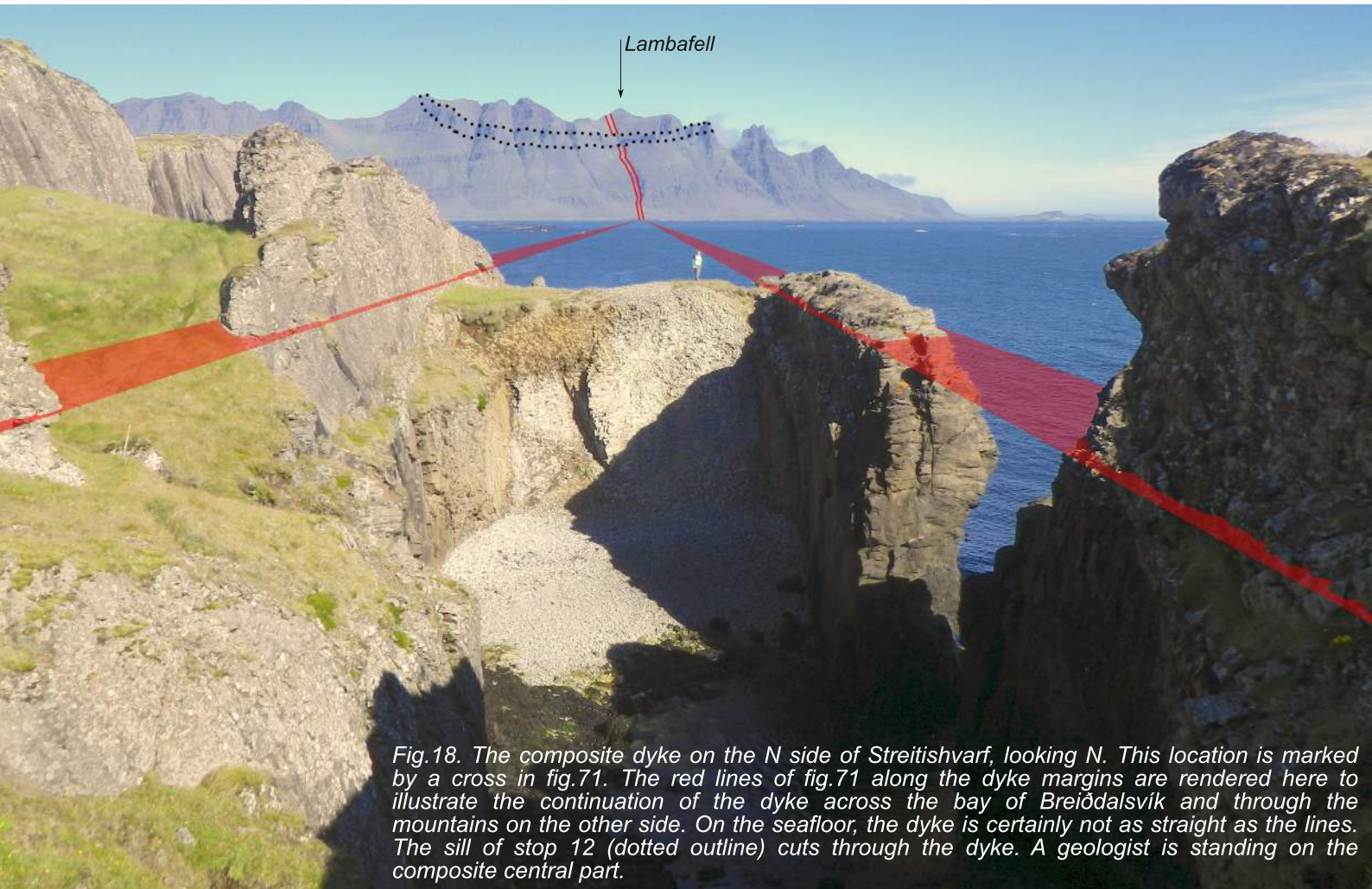


Fig.18. The composite dyke on the N side of Streitishvarf, looking N. This location is marked by a cross in fig.71. The red lines of fig.71 along the dyke margins are rendered here to illustrate the continuation of the dyke across the bay of Breiðdalsvík and through the mountains on the other side. On the seafloor, the dyke is certainly not as straight as the lines. The sill of stop 12 (dotted outline) cuts through the dyke. A geologist is standing on the composite central part.

be followed over a stretch of 15 km, from Streitishvarf through the mountain Lambafell above Breiðdalur and to the mountain side north of Stöðvarfjörður where it disappears. The outcrops reach an altitude of 700 m a.s.l. in Mt. Lambafell (fig.18 & 19). The dolerite margins only reach up to an altitude of ~400m a.s.l., for the remaining 300 m the dyke only consists of its felsic core. On a smaller scale, the dyke is curved and irregular; multiple intrusion and en echelon features are present. The thickness at Streitishvarf is ~25 m. The dyke thickens northwards and upwards, reaching >30 m at sea level in Stöðvarfjörður and ~30 m at 700 m altitude on Lambafell. It is hard to find the origin of the dyke, i.e. a volcanic centre or a dyke swarm. The Streitishvarf composite dyke is too far to the west and too old to be related to the Álftafjörður volcanic system. By the same token, the Sandfell laccolith and the Reyðarfjörður central volcano, both situated close to the northern end of the dyke, are too old to be a possible source for the Streitishvarf dyke. A dyke emplacement from N to S is indicated by magnetic measurements on the felsic central part of the dyke, and by greater dyke thickness in the N. Thus, the felsic melt should originate in an undiscovered magma chamber somewhere N of Stöðvarfjörður. If a mafic dyke intrudes a felsic magma body, it heats up the highly viscous felsic magma, making it more fluid. The felsic melt would thus be able to flow into and along the centre of the mafic dyke, insulated by the mafic melt. If such a dyke reaches the surface, a composite lava flow like the one in Berufjörður is erupted, stop 3.

Fig.19. A closer view over Breiðdalsvík bay. The Streitishvarf dyke cuts through Mt.Lambafell and forms a deep gully in the middle of the picture on the left, closer look from foot of Mt. Lambafell above. This part of the dyke was first described by Guppy & Hawkes, 1924. They called it the Hökulvík dyke.

Fig.20. Streitishvarf dyke, southern outcrop, seen to the south.

Fig.21. The composite rock of Streitishvarf dyke: Black basaltic part, bright rhyolitic part.

Stop 7

Breiðdalsvík

Dolerite sill, Walker Centre (Breiðdalssetur/Gamla Kaupfélagið), rock sample collection.

Location: 64,7918°N/14,0097°W, southern entrance to Breiðdalsvík village, the first house to the seaside.

Fig.22. The dolerite sill above Breiðdalsvík, highlighted in red. The sill transgresses the lava layers in the upper left. Also note the flow banding. The massive dolerite is exposed as high cliffs with extensive columnar jointing.
The Walker Centre is situated in the house in the lower right corner, officially named "Gamla Kaupfélagið" ("The old cooperative"). It is run by a non-profit company called Breiðdalssetur, which is the editor of this book.

Inside the Walker Centre, there is a mineral exhibiton and a rock collection of typical samples from the places visited in this book.

Prof. Dr. George Patrick Leonard Walker (1926-2005) was one of the world's leading volcanologists in the 20th century. He, along with his students, undertook pioneering and ground-breaking research on the geology in the East Fjords in the 1960s and 70s. They were the first to map the geology of the East Fjords in sufficient detail to enable accurate 3-dimensional reconstruction of the volcanic succession that makes up the Tertiary Formation in Iceland. He demonstrated that a majority of the lava flows, which he referred to as 'plateau basalts' (the gently inland dipping layers visible in the mountain slopes) were formed by fissure eruptions. Each of these eruptions was fed by one of the many north-south trending dykes that cross-cut the sequence. He also showed that the dykes cluster into swarms and that substantial lateral

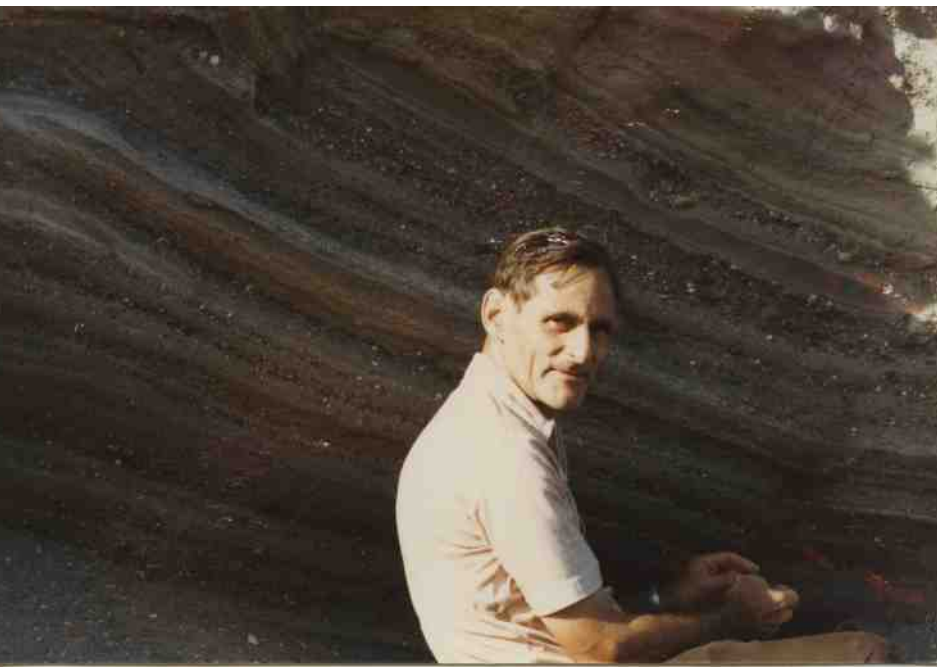


Fig.23. George Walker in his element. Hawaii, January 1984.

extension of the crust is required to their formation. At this time. the ideas behind plate tectonics were in their infancy and here, Walker had recognised one of its key concepts: crustal spreading.
Walker and his colleagues also identified a series of extinct central volcanoes in the region and demonstrated that each is closely associated with a dyke swarm. This work led to the identification of the primary building block of Icelandic geology, namely the 'volcanic system'.
Furthermore, he determined the elevation of the original land surface (i.e. the top of the volcanic succession) by three different methods and showed that they gave conclusive results, see p. . Walker also took many photographs on his expeditions to Iceland and they are an important source about human life in Iceland at the time.
Many of Walker's original documents and items are now preserved at Breiðdalssetur, such as his huge reprint collection of more than 3000 scientific papers and articles, his diaries, notebooks, photographs, thin sections, reports and maps.
As such, Breiðdalssetur serves as an educational and information centre on geology of East Iceland, underpinned by the work and legacy of this world renowned scientist.

Fig.24. (above) Silhouette of the rhyolite peaks between Berufjörður and Breiðdalur (Röndólfur Group of the Breiðdalur central volcano, see fig. 30), as seen from Dísarstaðafell in Breiðdalur, looking SW. By M. Gasser.

Fig.25. (below) Breiðdalsvík village and the broad valley, Breiðdalur. In the right foreground, the above-mentioned dolerite sill is forming a prominent grey cliff. In the right background, further up the valley, the bright yellowish acid rocks of the Breiðdalur central volcano are visible, see fig. 93. Left of it rises the chain of peaks between Berufjörður and Breiðdalur, also depicted at the top of this page and on fig. 29. Above all, on the horizon, the recent central volcanoes Snæfell, 1833m (middle), and Kverkfjöll, 1929m (left), on the rim of the Vatnajökull ice cap. Picture: S. G. Þórisson.

Stop 8

Breiðdalur central volcano, bottom view, Breiðdalur Valley

Bottom of fossil volcano edifice, overview internal structure of volcano flank

Location: 64,835°N/14,370°W .

This stop and stops 15 & 16 lead us through the interior of a fossil volcano. It was constructed about nine million years ago over a time span of roughly a million years. It is completely buried under flood basalts and represents an anomaly in the distinctly layered and gently inclined lava sequence. Due to erosion by the Ice Age glaciers, the anomaly is well exposed today. George Walker, by systematic mapping, recognized it as a volcanic edifice and called it the Breiðdalur Central Volcano (Walker, 1963). This work verified the existence of central volcanoes in the Tertiary. Like in currently active volcanic systems, they are aligned with a swarm of fissures/dykes.

In the mid-section of Breiðdalur valley, the layered lava pile changes in that a darker and more thinly bedded lava series is wedged into the thicker-bedded flood lava sequence. This a'a lavas characterize the mountains in the midsection of Breiðdalur (e.g. Mt. Tó, fig. 44) and represents the eastern flank of the

Fig.26 Lower stratigraphic contact of Breiðdalur Central Volcano, close to Hlíð in Breiðdalur. A thick lava flow at the top of the so-called Grænavatn porphyric group is beneath the red interlayer, the lavas of the Breiðdalur Central Volcano are above it. The location of this picture is marked by the white box in fig xx.

Fig.27. Zoom of white box in fig. 28. Yellow line: bottom of volcano.

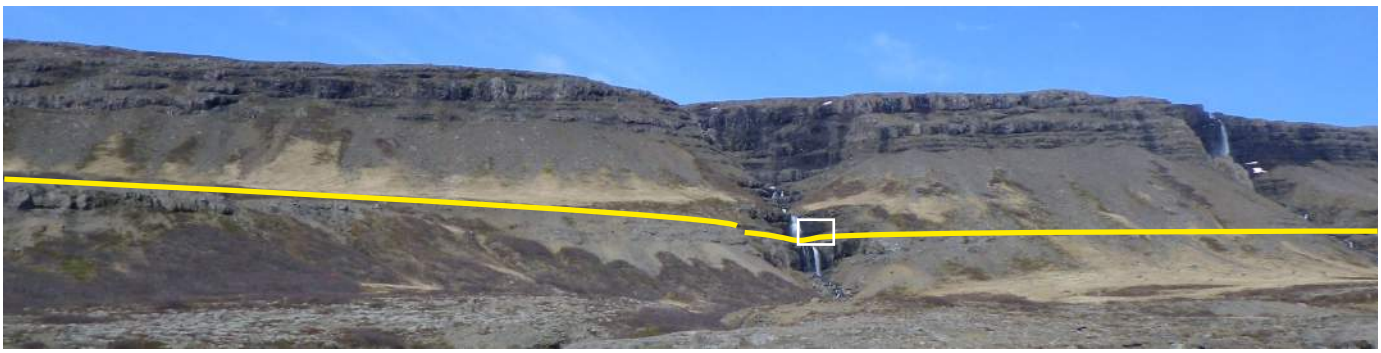
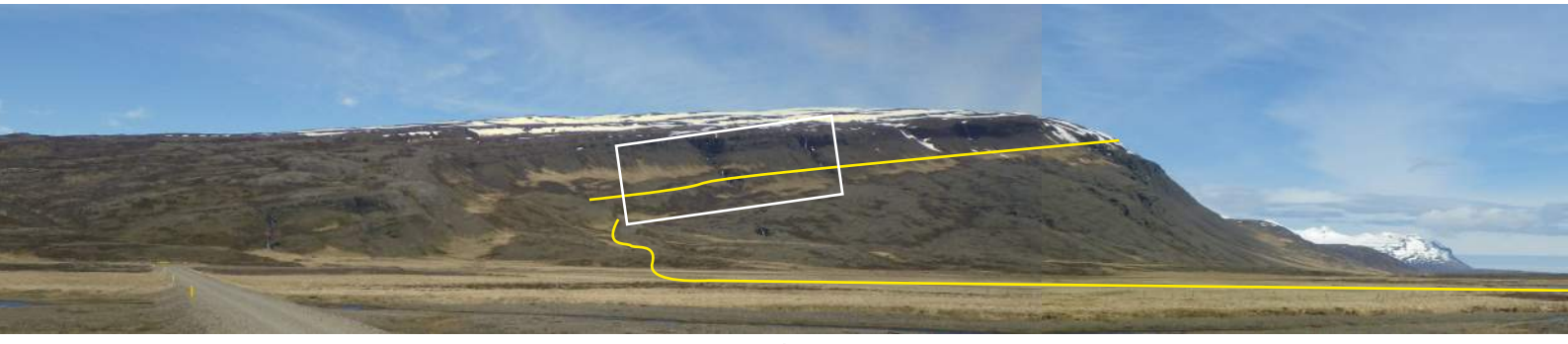


Fig.28. (below): Breiðdalur valley, view to the E from stop 13. The yellow line marks the bottom of the Breiðdalur Central volcano. White box: position of fig. . Red broken line: Andesite (icelandite) lavas.



fossil Breiðdalur central volcano. These basalt flows are thinner than identical flood basalts because they flowed down the slope of the volcano. Andesite lavas, also called icelandite, are another typical part of this lava series building the flanks of the volcano. They form thicker flows than the basalts and all originate from the centre. They become less numerous away from the volcano's core.
In the upper part of the valley, the layering of the succession becomes indistinct and disappears in places due to hydrothermal alteration (propylitization) in a cupola-like zone above the former, not exhumed magma chamber. This zone is topped by the so-called summit group, a sequence of thick and irregular brightly coloured silicic rocks. They fill in a caldera and form the top of the former mountain. It must have been a large shield volcano some 40km in diameter with an about 10km large caldera and very gentle slopes. Due to continuous flood lava eruptions from fissures on the surrounding plains, the mountain probably never stood much higher than half a kilometer above these plains. When its activity ceased, it was eventually buried under flood lava, readily visible on top of the summit group at the upper end of Breiðdalur valley.
The Grænavatn porphyric group, a marker horizon of plagioclase-phyric basalt lavas is immediately below the Breiðdalur volcano. The lavas and pyroclastic rocks that make up the volcano edifice above it are 1500m to 1800m thick.

The Breiðdalur volcano was first mapped in detail by George P.L. Walker in the early 1960s. He was the first to notice certain characteristics in the lava pile that point to the location and structure of the volcano:

-The lavas within the Breiðdalur volcano have a different inclination than surrounding flood lavas; They dip radially outwards from the centre area at 5-10° on the former slopes of the volcano, and they dip irregularly but generally inwards within the former caldera.
- The majority of the rocks in the core of a central volcano are silicic, while such rocks are almost absent from the succession outside of the volcano (e.g. the area immediately around Breiðdalsvík).
-Small irregular intrusions and dykes of basaltic to silicic composition are common in the vicinity of ancient volcanoes, and a dyke swarm often lies across their cores.
-Strongly hydrothermally altered rocks form a contact aureole around the core of the volcano.

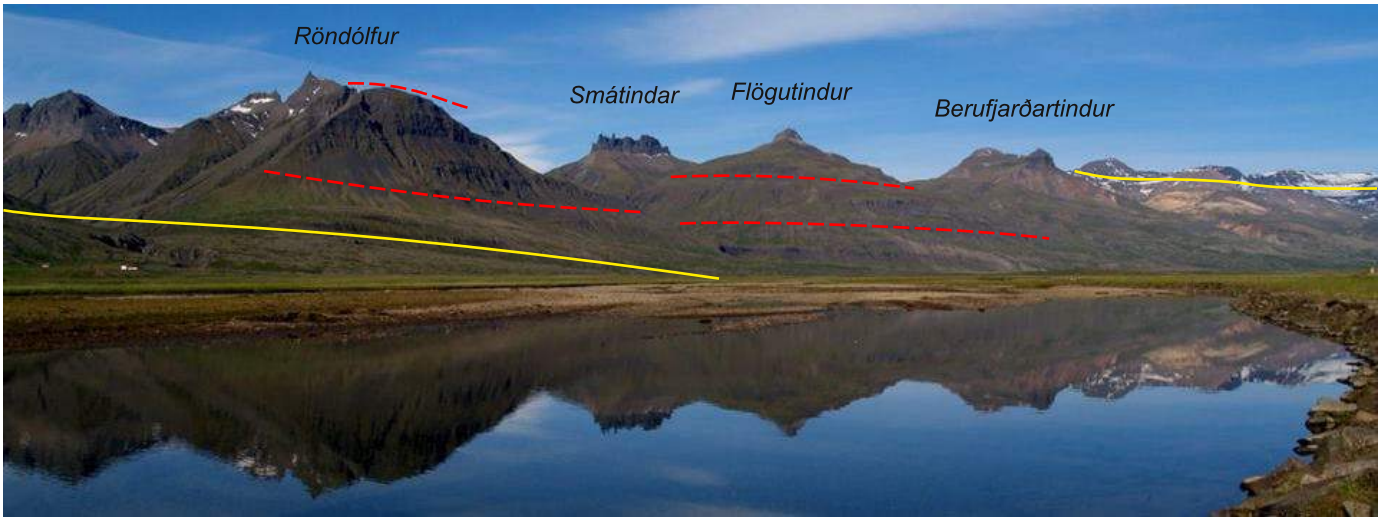
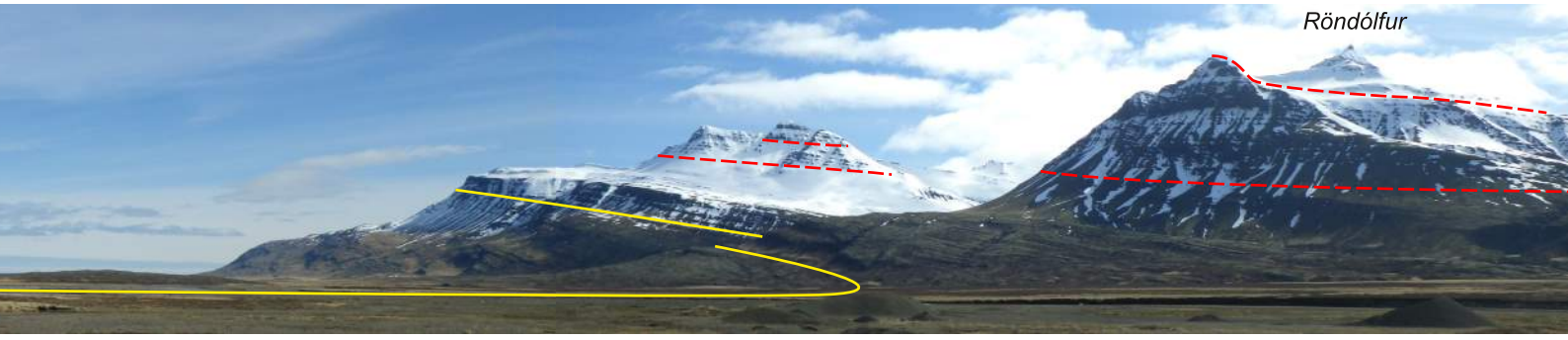


Fig.29. Breiðdalur valley, view to the W. Bottom and top of the central volcano are indicated by yellow lines, an andesite (icelandite) sequence is roughly outlined by red broken lines. Picture: H. Þórðardóttir



Stop 9

Breiðdalur central volcano

Overview of volcano flank to core transition

Location: 64,8525°N/14,3940°W

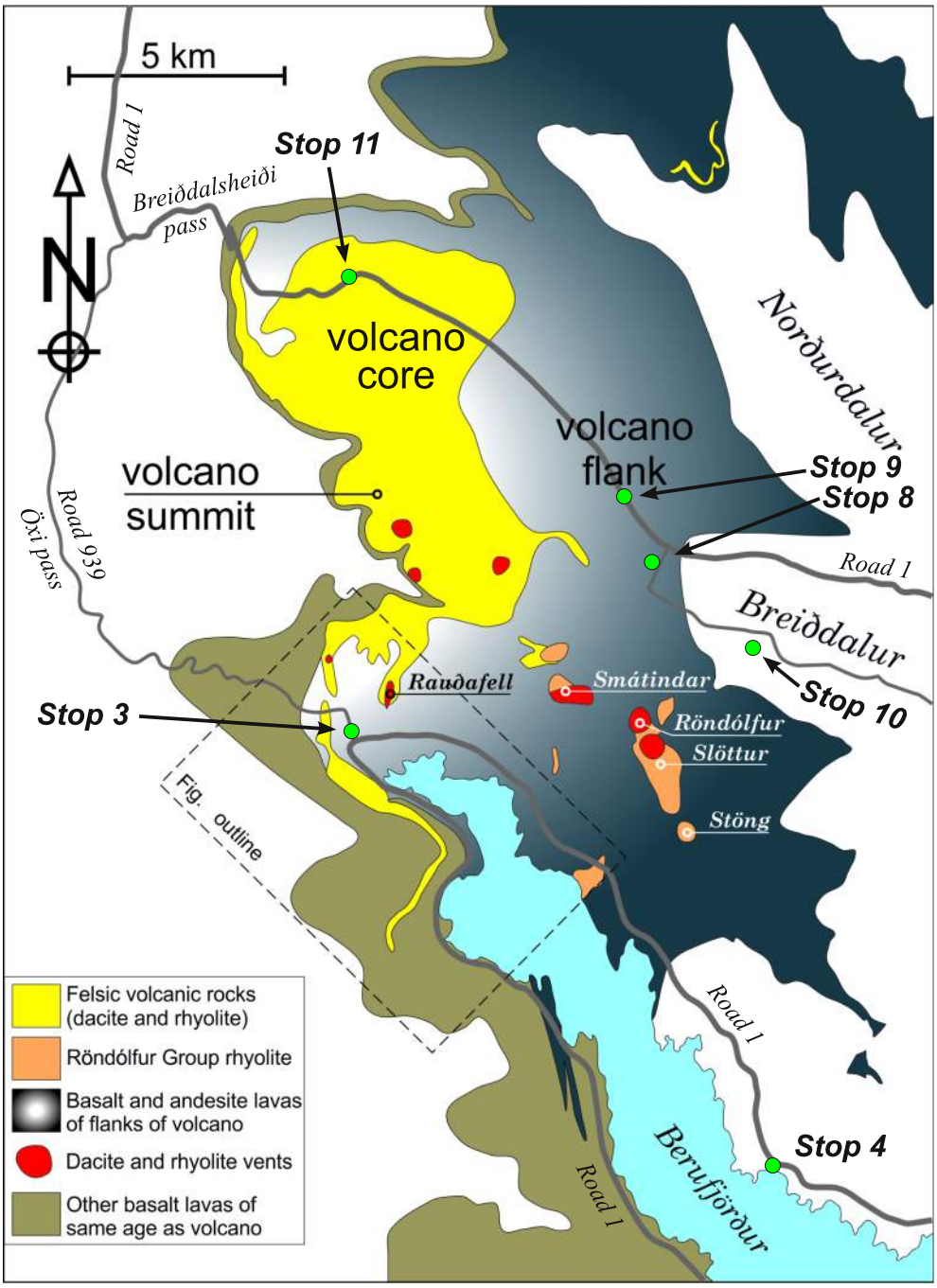


Fig.30. Simplified geological Map of Breiðdalur Central Volcano with locations of several stops described in this brochure. The outline of fig. 12 (stop 3) is also shown.

From Walker, 1963. Modified by Thordarson & Höskuldsson 2002, and Gasser 2014.

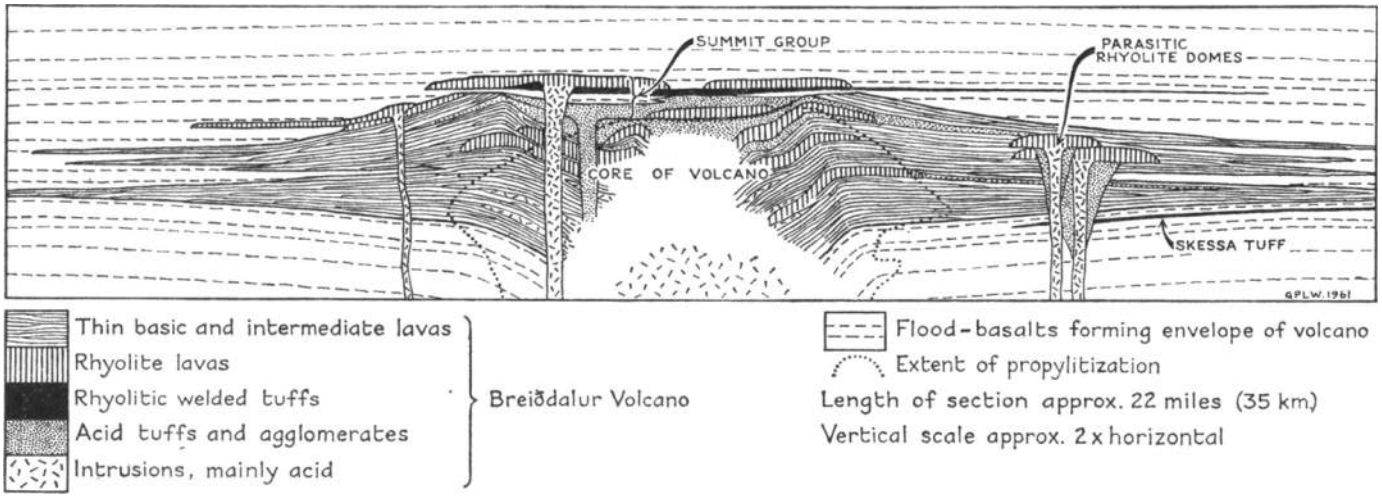


Fig.31. Schematic section of Breiðdalur Central Volcano. By George P. L. Walker, 1963. Vertical exaggeration 2x.

Park at the turnoff to Jórvík. Here, at the beginning of the upper part of Breiðdalur valley, we take a view at the inner structure of Breiðdalur Central Volcano. Looking SW towards the valley's other side, the layers of volcano flank lavas are well defined to the left but disappear more and more until, in the strongly altered core zone to the bottom right, layers are no more distinguishable. The upper part of this core zone is marked by thick yellowish bright rock units that were building the summit area of the volcano. These are silicic agglomerates, tuffs and lavas that filled in the volcano's caldera.
The caldera is not marked by ring faults as other calderas, but was probably formed by a down-sagging process. It was found by George Walker through measuring dip directions of layers and considering structural relationships as beautifully drawn on fig. 31. An example is the cliff of the triangular peak of Berufjarðartindur facing Breiðdalur valley (fig. 32). It is underlain by volcanic breccia (agglomerate) and consists of a series of palagonite breccia and pillow lava capped by subaerial lava. This features tell of an emplacement over a topographic rim into a depression that was water-filled at times, see also stop 11. In fig. 41, the inclination of the layering towards the caldera bottom is well visible below this cliff . One can even distinguish some bright rocks within the layered breccia. These are granophyre, granite and gabbro blocks, the only samples of plutonic rock in the region. They are telltale signs of a magma chamber underneath Breiðdalur Central Volcano, not unlike those of Vestra- and Eystrahorn.

Fig.32. Part of the view form above this stop to the SW. The distinctive layering of volcano flank lavas (left) disappears towards the core (right). The triangular cliff of Berufjarðartindur facing us in the upper middle of the picture is described in the text. See fig. 41 for the up-close view of Berufjarðartindur.

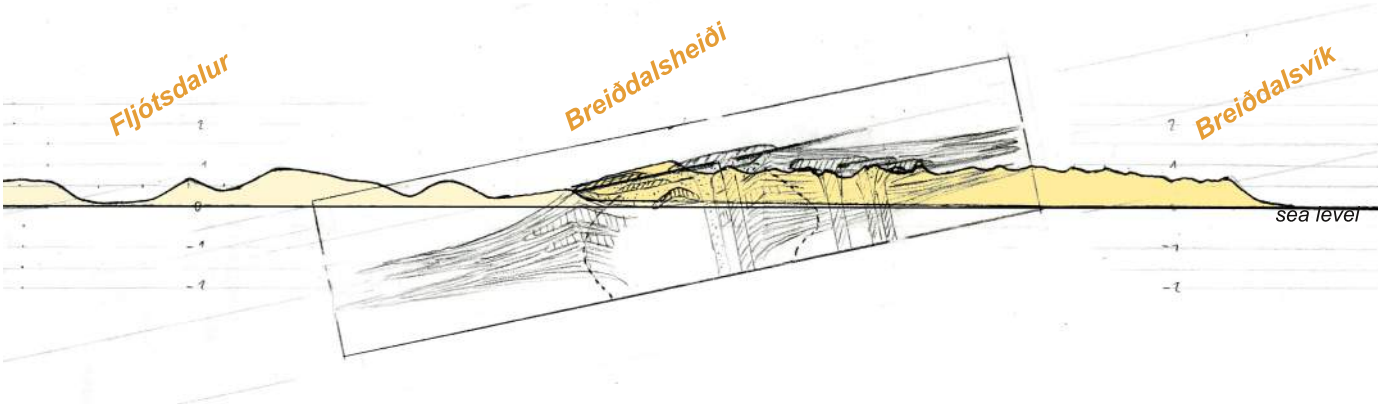


Fig.33. Coloured hand sketch showing the spatial position of Walker's profile of the fossil Breiðdalur Central Volcano (fig.31) in a topographic profile of Breiðdalur valley. The mountain range along the valley is shaded slightly darker yellow. By M. Gasser after Walker, 1963. Vertical exaggeration 2x.

Stop 10

Breiðdalur central volcano, skessa welded tuff

Marker horizon, probably one of the first eruptions of the Breiðdalur volcanic centre

Location: 64,8188°N/14,3337°W. Park on roadside, walk 300m up the river on its W side.

The rhyolitic Skessa welded tuff is the largest known ignimbrite layer in Iceland. It was formed by a pyroclastic density current that originated from a big explosive (plinian) eruption. Its vent area is located somewhere below Mt Röndólfur (fig 29 & 42). It is possible that this eruption initiated the growth of the Breiðdalur Central Volcano, because it must have originated from a somewhat evolved nearby magma chamber. The Skessa tuff is thickest in Breiðdalur closest to its source vents or 10-12m thick. Its thickness gradually tapers off to the north and is <2m at its distal end (i.e. north of Reyðarfjörður). Thus, the density current that produced the Skessa tuff swept northwards across the lava plains as a hot murky cloud overwhelming about 500km² of country. At its type locality about 500m above sea level, on the north face of Mt Skessa in Reyðarfjörður, it appears as a greenish layer about 3m thick and is the only felsic rock exposed in a 1000m thick section of basalt lavas. Closer to its source vent the ignimbrite exhibits a distinctive internal layering, as

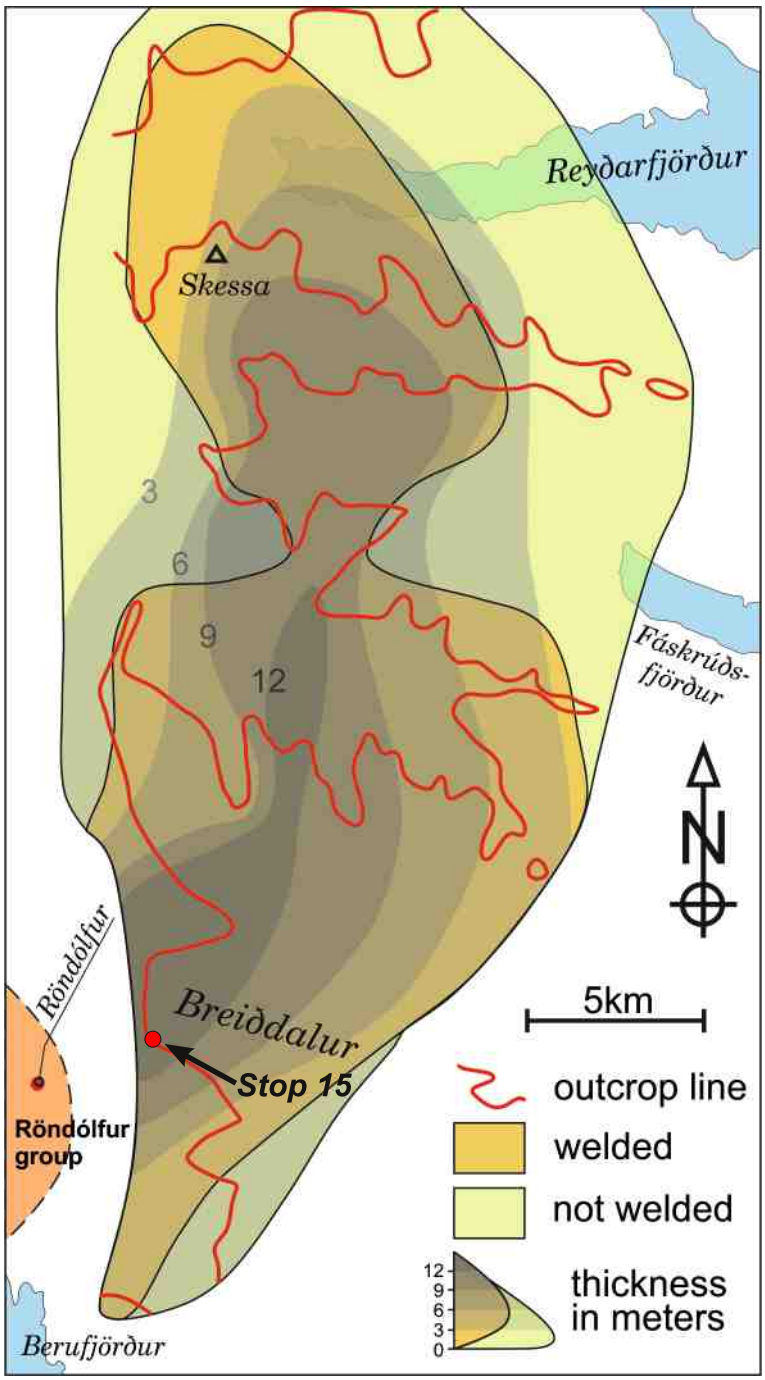


Fig.34. Outcrop map of Skessa Tuff showing the dispersal of the ignimbrite sheet. Original map from Walker, 1962, modified by Thordarson & Höskuldsson, 2002, and Gasser, 2014.

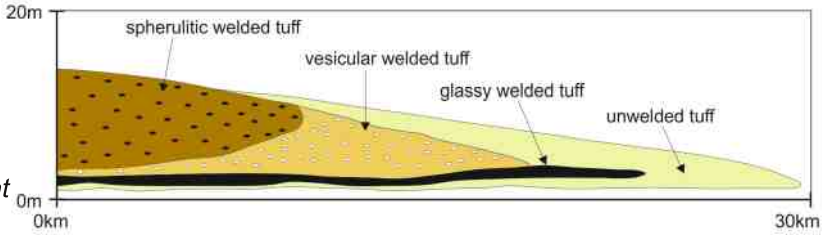


Fig.35.The internal structure of the ignimbrite. At the base is a veneer of non-welded tuff that is overlain by thin glassy welded tuff. The grey vesicular tuff grades sharply upwards into thicker pinkish stony spherulithic tuff, which is capped by a thin layer of non-welded tuff. Modified from Thordarson & Höskuldsson, 2002 and Walker, 1962.

Fig.36. The described outcrop of Skessa Tuff at river Skriðuá. By Gasser, 2015.

Stop 11

Breiðdalur central volcano, core and top view

Crater lake sediments, acid late stage volcanics, flood basalts burying volcano

Location: 64,890°N/14,541°W.

Parking is on the roadside some 200m above the bottom of the slope to Breiðdalsheiði pass. Walk down to Hesthalsá river and turn right to walk upstream along the river. The rock outcrops are pale green, very rubbly and cut by various dykes and sheets. The rock is hydrothermally altered (propylitized) almost beyond recognition. The green colour is caused by epidote that has replaced primary minerals and voids. Other hydrothermal minerals are pyrite, quartz, platy calcite, chlorite and laumontite.

The first outcrop is rhyolitic and can be followed for about 100m up to a forested part of the slope where the passage along the river gets a bit narrow and tricky. After that, another slope of greenish platy scree follows. This is a finely layered siltstone formed in a lake. Where the rock breaks into plates along the layers, ripples and ichnofossils (worm tracks) can be found. Millimeter-sized cubic pyrite crystals are common.

Here, a lake is presumed to have occupied the caldera floor of Breiðdalur Central Volcano similar to Öskjuvatn in Askja caldera today.

Fig.37. The outcrops at Hesthálsá are rather crumbly.

Fig.38. Professor Thordarson explaining the Breiðdalur Central Volcano. Hydrothermally altered core zone rocks at Blágil (blue canyon) in the background. The mountain top called Dýristindur in the middle of the picture consists of flood basalts overlying the fossil volcano's summit.

Fig.39 (next double page). George Walker's 1963 geological map of the Breiðdalur Central Volcano.

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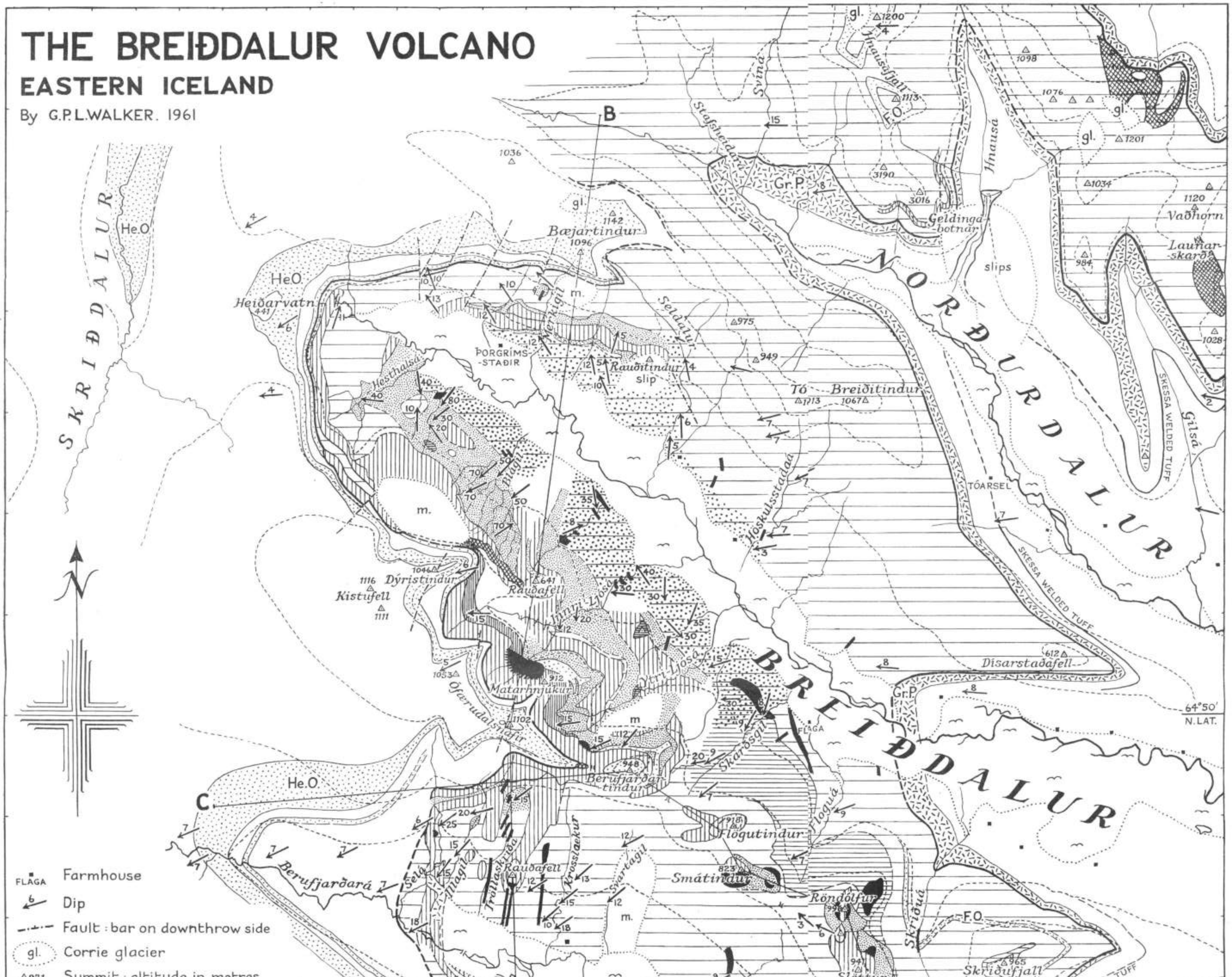

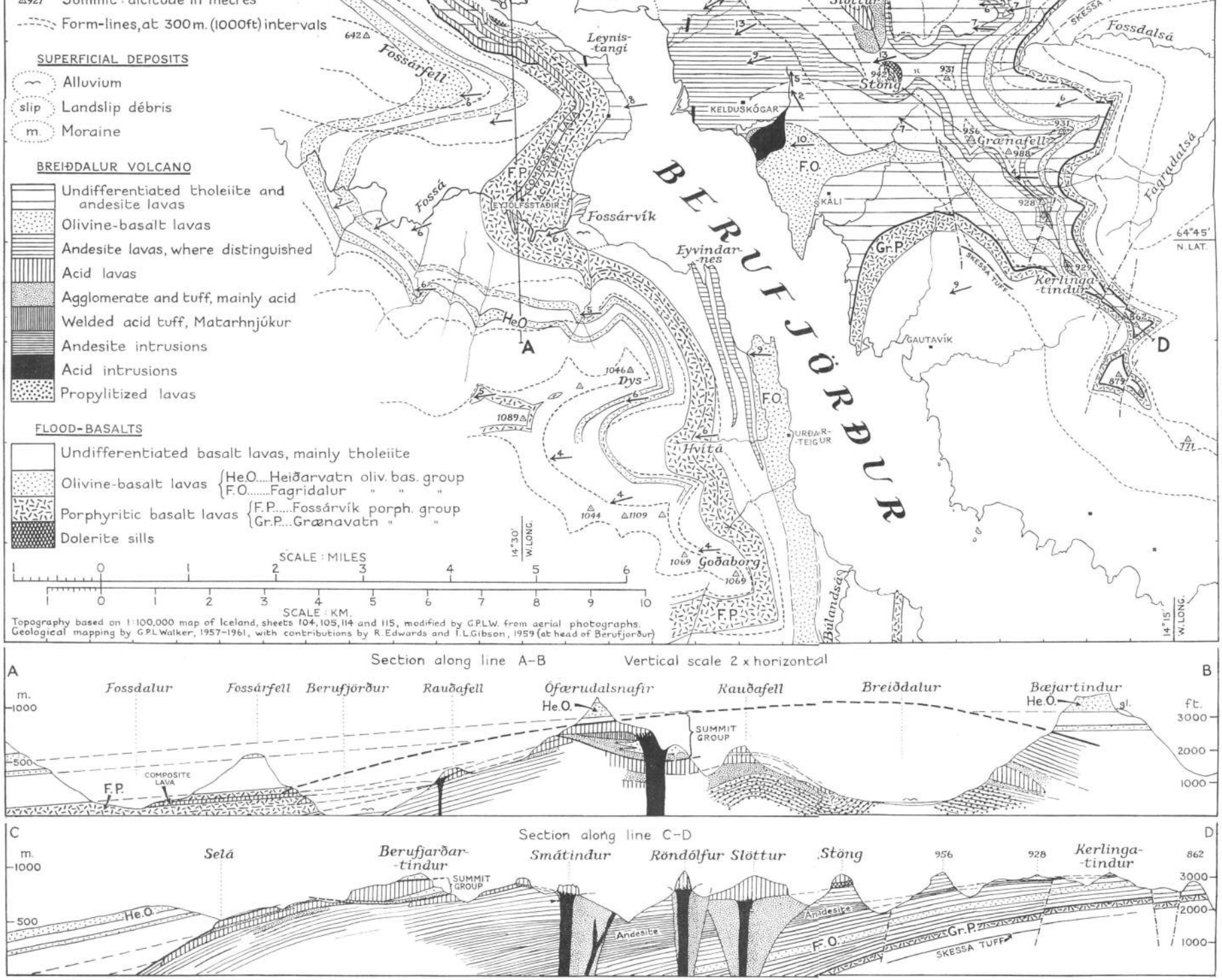
Summits : altitude in metres
Form-lines, at 300 m. (1000ft) intervals
SUPERFICIAL DEPOSITS
Alluvium
slip Landslip débris
m. Moraine
BREIÐDALUR VOLCANO
Undifferentiated tholeiite and andesite lavas
Olivine-basalt lavas
Andesite lavas, where distinguished
Acid lavas
Agglomerate and tuff, mainly acid
Welded acid tuff, Matarhnjúkur
Andesite intrusions
Acid intrusions
Propylitized lavas
FLOOD-BASALTS
Undifferentiated basalt lavas, mainly tholeiite
Olivine-basalt lavas {He.O....Heiðarvatn oliv. bas. group
F.O.....Fagridalur " " "
Porphyritic basalt lavas {F.P.....Fossárvík porph. group
Gr.P....Grænavatn " "
Dolerite sills
SCALE : MILES
SCALE : KM.
Topography based on 1:100,000 map of Iceland, sheets 104, 105, 114 and 115, modified by G.P.L.W. from aerial photographs.
Geological mapping by G.P.L. Walker, 1957–1961, with contributions by R. Edwards and I.L. Gibson, 1959 (at head of Berufjörður)
Fossárfell
Leynis-tangi
Fossá
Fossárvík
Eyvindar-nes
Dys
Hvítá
Goðaborg
Stöng
Grænafell
Kerlinga-tindur
Fossdalsá
Fagradalsá
Bulandsá
KELDUSKÓGAR
KÁLI
GAUTAVÍK
URÐAR-TEIGUR
EYJÓLFSSTAÐIR
SKESSA TUFF
64°45' N. LAT.
14°30' W. LONG.
14°15' W. LONG.
BERUFJÖRÐUR
Section along line A–B
Vertical scale 2 x horizontal
Fossdalur
Fossárfell
Berufjörður
Rauðafell
Ófærudalsnafir
Breiðdalur
Bæjartindur
SUMMIT GROUP
COMPOSITE LAVA
Section along line C–D
Selá
Berufjarðar-tindur
Smátindur
Röndólfur
Slöttur
Stöng
Kerlinga-tindur
Andesite

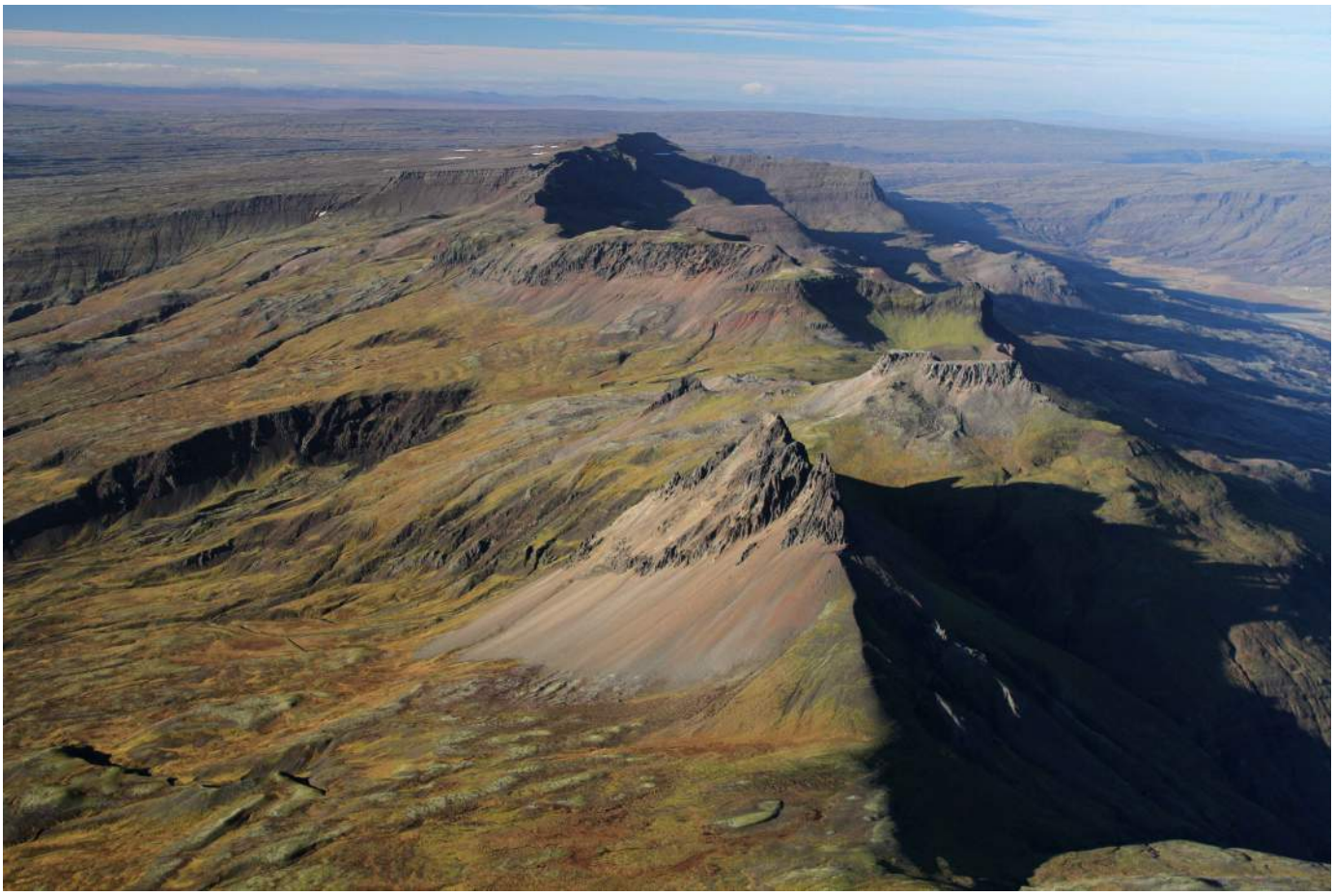

Fig.40. The mountain range between Berufjörður and Breiðdalur viewed to the west. Left: flood lavas banking up against the flank of the volcano, see also stop 3 fig. 10. Photo by Skarphéðinn G. Þórisson.

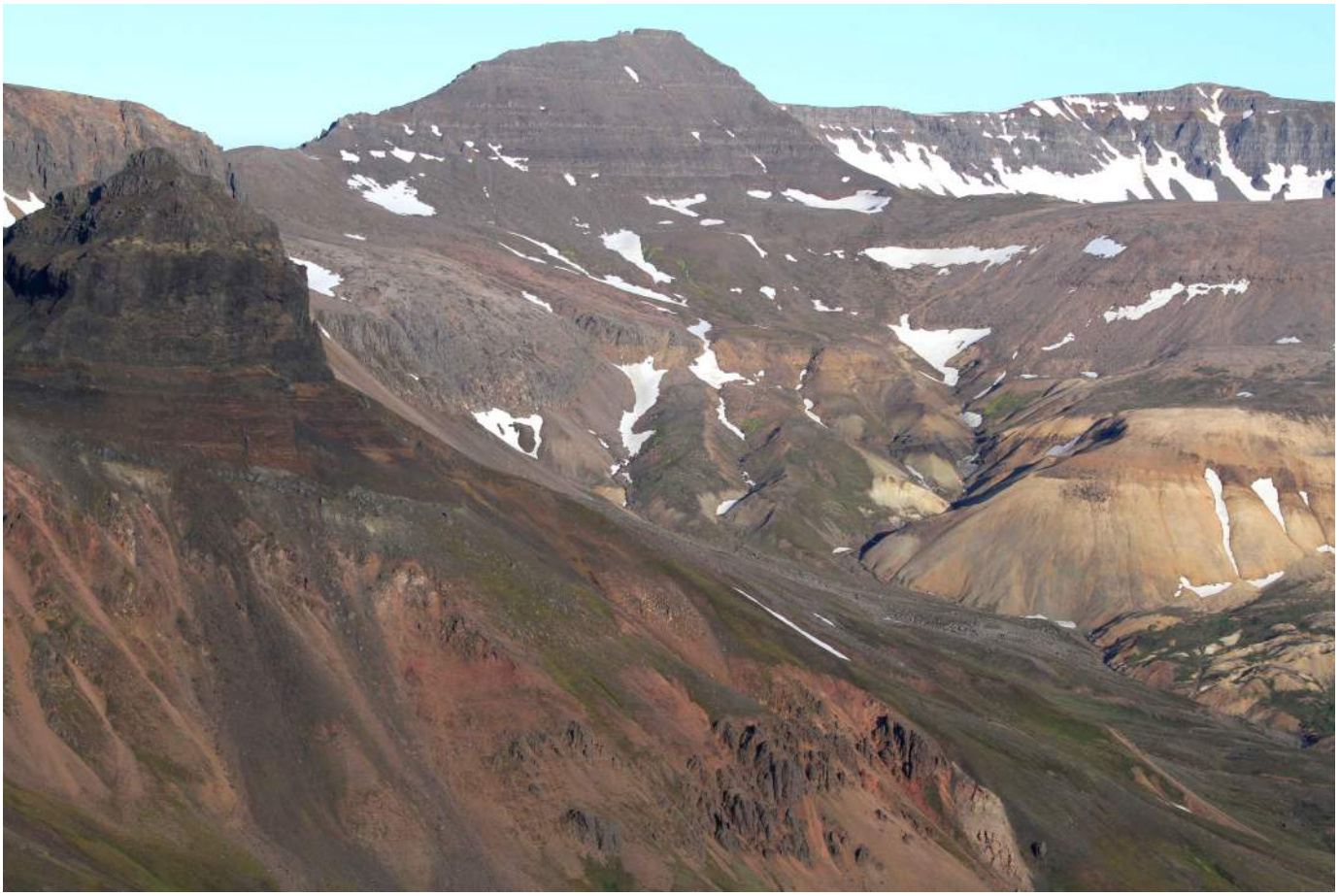

Fig.41. Inside the Breiðdalur volcano: The bright rocks on the right are rhyolithe of the core of the Breiðalur volcano. In the background)at the mountain tops) are the basaltic flood lavas burying the volcano. Photo by S. G. Þórisson.

Fig.42. The mountain range between Berufjörður and Breiðdalur viewed to the east. The peaks with light coloured talus slopes are rhyolite vents and plugs, located on the eastern flank of the ancient Breiðdalur volcano. From west to east they are: Flögutindur, Smátindar, Röndólfur, Slöttur and Stöng. The assumed origin of the Skessa ignimbrite is close to the mountains in the foreground. Photo by Skarphéðinn G. Þórisson.

Fig.43. Mount Tó, north of stop 9. It is entirely composed of rocks from the flank of Breiðdalur Central Volcano. Some cone sheets (inclined dykes presumably intruded from the volcano's magma chamber) are visible in the left foreground. Photo by Skarphéðinn G. Þórisson.